4.2.3 Transportation of Materials and Waste

Various chemicals and other materials being used for Y-12 operations are transported by truck using the above-addressed roads (SRs 58, 62, 95, and 170; I-40, I-75, and I-81). LLW, hazardous waste, and municipal and solid wastes are being generated by Y-12 operations. LLW is being stored on-site in temporary storage facilities and would eventually be disposed off-site at a DOE Site. A detailed description of Y-12 waste treatment and storage capabilities can be reviewed in Appendix A.5.

4.2.4 Other Transportation

Rail transport is available to Y-12 but is not currently being used.

TABLE 4.2.1–1.—*Existing Average Daily Traffic Flows (Vehicles per Day) on Oak Ridge Reservation Serving Y-12*

Road	To	From	Average Daily Traffic Vehicles/Day	Level of Service[a]
SR 58	SR 95	I-40	11,600	B
SR 95	SR 62	SR 58	16,440	D
SR 95	SR 58	I-40	8,058	A
SR 62	SR 95	SR	28,320	E
East Bear Creek Rd.	Eastbound	-	12,490	C
West Bear Creek Rd.	Westbound	-	3,200	A
East Bethel Valley Rd.	Eastbound	-	10,000	C
West Bethel Valley Rd.	Westbound	-	6,440	A

[a] LOS designations: A(Free Flow); B (Free Flow with maneuverability slightly impeded); C (Stable Flow maneuverability noticeably restricted); D (Stable Flow, reduced speed, maneuverability limited); E (Near capacity, speeds are low but relatively uniform).
Source: TDOT 1998.

4.3 SOCIOECONOMICS

This section describes current socioeconomic conditions within a ROI where more than 90 percent of the ORR workforce resides. The ROI is a four-county area in Tennessee comprised of Anderson, Knox, Loudon, and Roane Counties. Figure 4.3–1 shows the surrounding counties influenced by ORR. In 1997, almost 40 percent of the ORR workforce resided in Knox County, 29 percent in Anderson County, 16 percent in Roane County, and 6 percent in Loudon County. The remaining 9 percent of the workforce resides in other counties across Tennessee, none of which are home to more than 3 percent of the workforce (DOE 1999f).

TABLE 4.3.1–1.—*Employment by Sector (Percent)*

Sector	1980	1990	1998
Services	19.1	27.5[a]	30.2[a]
Wholesale and Retail	21.1	25.3[a]	24.7[a]
Government (including Federal, State, local, and military)	20.3	15.6	13.7
Manufacturing	21.9	15.9	13.0
Farm	2.0	1.6	1.2
Construction	4.9	5.4	6.1
Finance, Insurance, and Real Estate	6.0	5.2	6.5
Transportation and Public Utilities	3.7	4.0	4.5
Agricultural Service, Forestry, and Other	0.3	0.6	0.9
Mining	0.7	0.4	0.2

[a] Percentage only includes Knox and Loudon Counties. Data for Roane and Anderson Counties not available.
Source: BEA 1999.

4.3.1 Employment and Income

The ORR ROI has historically been dependent on manufacturing and government employment. More recent trends show growth in the service and wholesale and retail trade sectors and a decline in manufacturing and government employment. Table 4.3.1–1 presents current and historical employment for the major sectors of the ROI economy.

The ROI labor force grew by almost 15 percent in the first half of this decade from 243,209 in 1990 to 279,275 in 1995. There was a slight decline in the labor force between 1995 and 1998 when it totaled 278,866. ROI employment grew from 231,822 in 1990 to 268,748 in 1995 and continued to grow despite the decline in the labor force and totaled 269,466 in 1998 (BLS 1999).

The ROI unemployment rate was 3.4 percent in 1998, the lowest level in over a decade, as shown in Table 4.3.1–2. Unemployment rates within the ROI ranged from a low of 3.1 percent in Knox County to a high of 5 percent in Roane County. The unemployment rate in Tennessee was 4.2 percent in 1998 (BLS 1999).

Source: LMER 1999a.

FIGURE 4.3–1.—*Location of Oak Ridge Reservation and Surrounding Counties.*

Per capita income in the ROI was $23,520 in 1997, a 35 percent increase from the 1990 level of $17,407. Per capita income in 1997 in the ROI ranged from a low of $19,564 in Roane County to a high of $24,688 in Knox County. The per capita income in Tennessee was $22,699 in 1997 (BEA 1999).

TABLE 4.3.1–2.—*Region of Influence Unemployment Rates (Percent)*

County	1990	1991	1992	1993	1994	1995	1996	1997	1998
Anderson	4.8	5.1	5.4	4.9	3.9	3.9	4.8	5.5	3.6
Knox	4.1	4.5	4.5	3.9	3.3	3.4	3.4	3.6	3.1
Loudon	5.7	7.0	5.6	4.6	3.9	4.0	3.9	4.6	3.2
Roane	8.3	8.2	8.5	5.7	4.4	5.8	5.3	7.3	5.0
ROI Total	4.7	5.0	5.0	4.3	3.6	3.6	3.6	4.3	3.4
Tennessee	5.3	6.7	6.4	5.7	4.8	5.2	5.2	5.4	4.2

Source: BLS 1999.

Y-12 employs approximately 8,900 workers, including DOE employees and multiple contractors. DOE has a significant impact on the economy of the ROI and Tennessee. As a whole, DOE employees and contractors number more than 13,700 individuals in Tennessee, primarily in the ROI. These jobs have a higher average salary than the statewide average, $40,000 compared to $25,695 (BEA 1999). DOE employment and spending generate additional benefits to the ROI and state economies through the creation of additional jobs in sectors providing support to DOE and its workers.

4.3.2 Population and Housing

Between 1960 and 1990, population growth in the ROI was slower than population growth in Tennessee as a whole. The ROI population increased at an average annual rate of 1 percent while the state population increased 1.2 percent annually. Between 1990 and 1998, ROI population growth increased 1.1 percent annually while the state population increased 1.4 percent annually. Loudon County experienced the fastest rate of population growth, averaging 3.1 percent annually between 1990 and 1998, while Anderson County population has increased an average of 0.5 percent annually (Census 1995, Census 1999). Population in all counties in the ROI is projected to continue to grow at a somewhat slower rate between 1998 and 2020, as shown in Table 4.3.2–1.

Knox County is the largest county in the ROI with a 1998 population of 366,846. Knox County includes the city of Knoxville, the largest city in the ROI. Loudon County is the smallest county in the ROI with a total population of 39,052. The city of Oak Ridge and the ORR are located in both Anderson and Roane Counties with 1998 populations of 71,116 and 50,026, respectively (Census 1999).

TABLE 4.3.2–1.—*Historic and Projected Population in the Region of Influence*

County	1960	1970	1980	1990	1998	2000	2010	2020
Anderson	60,032	60,300	67,346	68,250	71,116	72,502	76,000	79,275
Knox	250,523	276,293	319,694	335,749	366,846	374,616	404,666	432,866
Loudon	23,757	24,266	28,553	31,255	39,052	39,761	44,941	50,238
Roane	39,133	38,881	48,425	47,227	50,026	50,829	54,433	58,113
ROI	373,445	399,740	464,018	482,481	527,040	537,708	580,040	620,492
Tennessee	3,567,089	3,923,687	4,591,120	4,877,203	5,430,621	5,533,762	6,062,695	6,593,194

Source: Census 1995, Census 1999, BEA 1999.

TABLE 4.3.2–2.—*Region of Influence Housing Characteristics (1990)*

County	Total Number of Housing Units	Number of Owner-Occupied Units	Owner-Occupied Vacancy Rates (percent)	Median Value	Number of Occupied Rental Units	Rental Vacancy Rates (percent)	Median Monthly Contract Rent
Anderson	29,323	19,401	1.1	$55,100	7,983	9.3	$262
Knox	143,582	85,369	1.9	$63,900	48,270	8.4	$272
Loudon	12,995	9,428	1.7	$51,000	2,727	7.2	$190
Roane	20,334	14,102	1.4	$48,700	4,351	9.9	$194
ROI	206,234	128,300	NA	NA	63,331	NA	NA

Note: NA - Not applicable.
Source: Census 1992.

There were a total of 206,234 housing units in the ROI in 1990. A summary of ROI housing characteristics is shown in Table 4.3.2–2. Approximately 67 percent of these units were single family homes, 24 percent were multifamily units, and 8 percent were mobile homes. Approximately 7 percent of the housing units were vacant, although some vacant units were used for seasonal, recreational, or other occasional purposes. Rental vacancy rates ranged from 7.2 percent in Loudon County to 9.9 percent in Roane County while homeowner vacancy rates ranged from 1.1 percent in Anderson County to 1.9 percent in Knox County.

Owner-occupied housing units accounted for 62 percent of the total housing units while renter-occupied units accounted for approximately 31 percent (Census 1992).

In 1990, the median value of owner-occupied housing units ranged from $48,700 in Roane County to $63,900 in Knox County, while the median contract rent ranged from $190 in Loudon County to $272 in Knox County.

4.3.3 Community Services

Community services in the ROI include public schools, law enforcement, and medical services.

Eight public school districts with a total of 144 schools provide educational services for the approximately 78,000 students in the ROI. Higher education opportunities in the ROI include the University of Tennessee as well as several private colleges and two community colleges (HPI 1999a).

Law enforcement is provided by 20 municipal, county, and local police departments that employ over 1,500 officers and civilians. Security at Y-12 was provided by LMES employees until January 10, 2000, when the protective force and selected security work was contracted to Wackenhut Services, Inc. (HPI 1999b).

There are 13 hospitals in the ROI with a total of 2,833 beds. These hospitals operate at an average of 67 percent occupancy (AHA 1995). There are 1,525 doctors in the ROI with the majority (1,279) in Knox County (AMA 1996).

4.4 GEOLOGY AND SOILS

4.4.1 Physiography

ORR lies in the Valley and Ridge Physiographic Province of eastern Tennessee. The topography consists of alternating valleys and ridges that have a northeast-southwest trend, with most ORR facilities occupying the valleys. In general, the ridges consist of resistant siltstone, sandstone, and dolomite units, and the valleys, which resulted from stream erosion, consist of the less-resistant shales and shale-rich carbonates (DOE 1991b).

The topography within the ORR ranges from a low of 229 m (750 ft) above mean sea level (MSL) along the Clinch River to a high of 384 m (1,260 ft above) MSL along Pine Ridge. Within the ORR, the topographic relief between the valley floors and ridge crests is generally about 91 to 107 m (300 to 350 ft) (LMER 1999a).

4.4.2 Geology

ORR Geology. Several geologic formations are present in the ORR area. A geologic map and stratigraphic column of the area are shown in Figures 4.4.2–1 and 4.4.2–2, respectively. The Rome Formation, which is present north of Y-12 and forms Pine Ridge, consists of massive to thinly bedded sandstones interbedded with minor amounts of thinly bedded, silty mudstones, shales, and dolomites. In the ORR area, the stratigraphic thickness of the Rome Formation is uncertain because of the displacement caused by the White Oak Mountain Thrust Fault. The Conasauga Group, which underlies Bear Creek Valley, consists primarily of calcareous shales, siltstone, and limestone. The Knox Group, which is present immediately south of Y-12, can be divided into five formations of dolomite and limestone. All five formations have been identified at the ORR. The Knox Group, which underlies Chestnut Ridge, is estimated to be approximately 732 m (2,400 ft) thick. The Knox Group weathers to a thick, orange-red, clay residuum that consists of abundant chert and contains karst features (DOE 1991b).

Karst features are dissolutional features occurring in carbonate bedrock. Karst features represent a spectrum ranging from minor solutional enlargement of fractures to conduit flowpaths to caves large enough for a person to walk into. Numerous surface indications of karst development have been identified at ORR (Figure 4.4.2–3). Surface evidence of karst development includes sinking streams (swallets) and overflow swallets, karst springs and overflow springs, accessible caves, and numerous sinkholes of varying size. In general, karst appears most developed in association with the Knox Group carbonate bedrock, as the highest density of sinkholes occurs in this group (LMER 1999a).

ORR Seismology. The Oak Ridge area lies at the boundary between seismic Zones 1 and 2 of the Uniform Building Code, indicating that minor to moderate damage could typically be expected from an earthquake (Table 4.4.2–1). Since the New Madrid earthquakes of 1811 to 1812, at least 26 other earthquakes with a Modified Mercalli intensity, herein referred to as intensity, of III to VI have been felt in the Oak Ridge area, the majority of these having occurred in the Valley and Ridge Province. The Charleston, South Carolina, earthquake of 1886 had an intensity of VI at Oak Ridge, and an earthquake centered in Giles County, Virginia, in 1886 produced an intensity of IV to V at Oak Ridge. One of the closest seismic events to ORR occurred in 1930; its epicenter was 8 km (5 mi) from ORR (DOE 1996e). This earthquake had an estimated intensity of VII at the epicenter and an approximate intensity of V to VI in the Oak Ridge area. Maximum horizontal ground surface accelerations of 0.06 to 0.30 of acceleration due to gravity at ORR are estimated to result from an earthquake that could occur once every 500 to 2,000 years.

FIGURE 4.4.2–1.—*Geological Map of the Y-12 Site.*

Source: Sutton and Field (1995).

Source: DOE 1998b.

FIGURE 4.4.2–2.*—Generalized Stratigraphic in the Y-12 Characterization Area.*

An earthquake occurred in 1973 in Maryville, TN, 34 km (21 mi) southeast of ORR, and had an estimated intensity of V to VI in the Oak Ridge area (DOE 1996b). In 1987, a significant earthquake occurred approximately 48 km (30 mi) from ORR with an intensity of VI. In addition, since 1995, two earthquakes with an intensity of III and two earthquakes with an intensity of V occurred within 160 km (100 mi) of the ORR (NEIC 1999). In 1998, one earthquake that had an intensity of III occurred approximately 3 km (1.9 mi) from the ORR. There have been 13 earthquakes in the last 155 years that at their epicenter produced an intensity of VI and one of intensity VII within 166 km (100 mi) of ORR (NEIC 1999).

There is no volcanic hazard at ORR. The area has not experienced volcanism within the last 230 million years. Therefore, no present or future volcanic activity is expected (DOE 1996e).

Y-12 Seismology. Y-12 is cut by many inactive faults formed during the late Paleozoic Era (DOE 1996e). There is no evidence of capable faults in the immediate area of Oak Ridge, as defined by 10 CFR 100 (surface movement within the past 35,000 years or movement of a recurring nature within the past 500,000 years). The nearest capable faults are approximately 480 km (300 mi) west of ORR in the New Madrid Fault zone.

Y-12 Geology. Y-12 is located within Bear Creek Valley, which is underlain by Middle to Late Cambrian strata of the Conasauga Group (see Figure 4.4.2–1). The Conasauga Group consists primarily of highly fractured and jointed shale, siltstone, calcareous siltstone, and limestone in the site area. The upper part of the group is mainly limestone, while the lower part consists of mostly shale (LMER 1999a). This group can be divided into six discrete formations, which are, in ascending order, the Pumpkin Valley Shale, the Rutledge Limestone, the Rogersville Shale, the Maryville Limestone, the Nolichucky Shale, and the Maynardville Limestone. The thickness of each of these formations varies throughout the Conasauga Group. The bedrock at the Y-12 Site is adequate to support structures using standard construction techniques.

Bedrock in the Y-12 area is overlain by alluvium, colluvium, man-made fill, fine-grained residuum from the weathering of the bedrock, saprolite, and weathered bedrock. The overall thickness of these materials in the Y-12 area is typically less than 12 m (40 ft). In undeveloped areas of the Y-12, the saprolite (a transitional mixture of fine-grained residuum and bedrock remains) retains primary textural features of the unweathered bedrock, including fractures (HSW 1994).

Numerous dissolution and karst features are the primary geological features influencing Y-12 (see Figure 4.4.2–3). Y-12 is situated on carbonate bedrock such that groundwater flow and contaminant transport are controlled by solution conduits in the bedrock. These karst features, including large fractures, cavities, and conduits, are most widespread in the Maynardville Limestone, a formation underlying Y-12, and the Knox Group. These cavities and conduits are often connected and typically found at depths greater than approximately 33 m (100 ft) (DOE 1998b).

FIGURE 4.4.2–3.—*Geology and Karst Features.*

TABLE 4.4.2–1.—*The Modified Mercalli Intensity Scale of 1931, With Approximate Correlations to Richter Scale and Maximum Ground Acceleration*[a]

Modified Mercalli Intensity[b]	Observed Effects of Earthquake	Approximate Richter Magnitude[c]	Maximum Ground Acceleration[d]
I	Usually not felt	<2	negligible
II	Felt by persons at rest, on upper floors or favorably placed	2-3	<0.003 g
III	Felt indoors; hanging objects swing; vibration like passing of light truck occurs; might not be recognized as earthquake	3	0.003 to 0.007 g
IV	Felt noticeably by persons indoors, especially in upper floors; vibration occurs like passing of heavy truck; jolting sensation; standing automobiles rock; windows, dishes, and doors rattle; wooden walls and frames may creak	4	0.007 to 0.015 g
V	Felt by nearly everyone; sleepers awaken; liquids disturbed and may spill; some dishes break; small unstable objects are displaced or upset; doors swing; shutters and pictures move; pendulum clocks stop or start	4	0.015 to 0.03 g
VI	Felt by all; many are frightened; persons walk unsteadily; windows and dishes break; objects fall off shelves and pictures fall off walls; furniture moves or overturns; weak masonry cracks; small bells ring; trees and bushes shake	5	0.03 to 0.09 g
VII	Difficult to stand; noticed by car drivers; furniture breaks; damage moderate in well built ordinary structures; poor quality masonry cracks and breaks; chimneys break at roof line; loose bricks, stones, and tiles fall; waves appear on ponds and water is turbid with mud; small earthslides; large bells ring	6	0.07 to 0.22 g
VIII	Automobile steering affected; some walls fall; twisting and falling of chimneys, stacks, and towers; frame houses shift if on unsecured foundations; damage slight in specially designed structures, considerable in ordinary substantial buildings; changes in flow of wells or springs; cracks appear in wet ground and steep slopes	6	0.15 to 0.3 g
IX	General panic; masonry heavily damaged or destroyed; foundations damaged; serious damage to frame structures, dams and reservoirs; underground pipes break; conspicuous ground cracks	7	0.3 to 0.7g
X	Most masonry and frame structures destroyed; some well built wooden structures and bridges destroyed; serious damage to dams and dikes; large landslides; rails bent	8	0.45 to 1.5 g
XI	Rails bent greatly; underground pipelines completely out of service	9	0.5 to 3 g
XII	Damage nearly total; large rock masses displaced; objects thrown into air; lines of sight distorted	9	0.5 to 7 g

[a] This table illustrates the approximate correlation between the Modified Mercalli intensity scale, the Richter scale, and maximum ground acceleration.
[b] Intensity is a unitless expression of observed effects.
[c] Magnitude is an exponential function of seismic wave amplitude, related to the energy released.
[d] Acceleration is expressed in relation to the earth's acceleration due to earth's gravity (g).
Source: NEIC 1999.

4.4.3 Soils

ORR Soils. Bear Creek Valley lies on well to moderately well-drained soils underlain by shale, siltstone, and silty limestone. Developed portions of the valley are designated as urban land. Soil erosion from past land uses has ranged from slight to severe. Erosion potential is very high in those areas that have been eroded in the past with slopes greater than 25 percent. Erosion potential is lowest in the nearly flat-lying permeable soils that have a loamy texture. Additionally, shrink-swell potential is low to moderate and the soils are generally acceptable for standard construction techniques (DOE 1996e).

Y-12 Soils. Y-12 lies on soils of the Armuchee-Montevallo-Hamblen, the Fullerton-Claiborne-Bodine, and the Lewhew-Armuchee-Muskinghum associations. Soil erosion due to past land use has ranged from slight to severe. Wind erosion is slight and shrink-swell potential is low to moderate. Finer textured soils of the Armuchee-Montevallo-Hamblen association have been designated as prime farmland when drained (DOE 1993). The soils at the Y-12 Site are generally stable and acceptable for standard construction techniques.

4.5 HYDROLOGY

This section describes the surface and groundwater resources on the ORR in general and Y-12 specifically. Much of the information for the Y-12 water resources, particularly surface water and groundwater quality, are based on the results of recent CERCLA Remedial Investigations conducted in Bear Creek Valley (DOE 1997a) and UEFPC (DOE 1998b).

4.5.1 Surface Hydrology

ORR Surface Drainage Systems. The major surface water body in the immediate vicinity of the ORR is the Clinch River, which borders the site to the south and west. There are four major subdrainage basins on the ORR that flow into the Clinch River and are affected by site operations: Poplar Creek, East Fork Poplar Creek, Bear Creek, and White Oak Creek. Drainage from Y-12 enters both Bear Creek and EFPC; ETTP drains predominantly into Poplar Creek and Mitchell Branch; and ORNL drains into the White Oak Creek drainage basin (DOE 1992). Several smaller drainage basins, including Ish Creek, Grassy Creek, Bearden Creek, McCoy Branch, Kerr Hollow Branch, and Raccoon Creek, drain directly in to the Clinch River. Each drainage basin takes the name of the major stream flowing through the area. Within each basin are a number of small tributaries. The natural surface water bodies in the vicinity of ORR are shown in Figure 4.5.1–1.

Y-12 Surface Drainage Systems. Within the Y-12 area the two major surface water drainage basins are those of Bear Creek and EFPC. The upper reaches of EFPC drain the majority of the industrial facilities of Y-12. The in-plant portion of EFPC has been designated as UEFPC.

The natural drainage pattern of UEFPC has been radically altered by the construction of Y-12. The western portion of the creek flows underground through pipes and the remaining portion flows in a modified and straightened channel lined with riprap and concrete. Flow in UEFPC is derived partially from groundwater captured by the buried channels and funneled to the creek. In addition, outfalls into UEFPC add a combination of groundwater, storm water, and water generated by plant operations (e.g., basement sumps, treatment plant discharges). As a result of reduced operations and elimination of inadvertent direct discharges of contaminated water to UEFPC, flow in UEFPC decreased from 38-57 MLD (10-15 MGD) in the mid-1980s to about 9 MLD (2.5 MGD) in the mid-1990s. To improve downstream water quality (e.g., toxicity requirements, temperature), Y-12's 1995 National Pollutant Discharge Elimination System (NPDES) permit required supplementing flow in UEFPC by the addition of raw water from the Clinch River. Since mid-1996, water has been added to the western portion of the open channel in order to maintain flow of 26 MLD (7 MGD) at Station 17, just before the creek exits Y-12 on the east end.

Bear Creek Valley west of Y-12 is drained by Bear Creek. Bear Creek begins near the westernmost portion of Y-12 and flows west for approximately 8.3 km (5 mi). When Bear Creek reaches U.S. Highway 95, it turns north and flows through a water gap in Pine Ridge to its confluence with Lower EFPC just above its confluence with Poplar Creek. Bear Creek flow is maintained by inputs from tributary streams flowing in from the north (mostly) from Pine Ridge. Flow in Bear Creek is further supplemented by discharges from several springs at the base of Chestnut Ridge (entering Bear Creek from the south). The channel of Bear Creek is less modified than that of UEFPC but several short reaches have been relocated to accommodate construction (e.g., Bear Creek Road) at the west end of Y-12.

The Clinch River and connected waterways supply all raw water for ORR and provide potable water for Y-12, ORNL, and the city of Oak Ridge. The Clinch River has an average flow of 132 m^3/s (4,647 ft^3/s) as measured at the downstream side of Melton Hill Dam at mile 23.1. The average flow of Bear Creek near Y-12 is 0.11 m^3/s (3.9 ft^3/s). Prior to flow augmentation in UEFPC, the average flow in EFPC measured downstream of Y-12 was 1.3 m^3/s (45 ft^3/s). The average flow in EFPC has increased as flow augmentation raised the minimum flow rate to 0.3 m^3/s (11 ft^3/s) in the headwaters of UEFPC. Y-12 uses approximately 7,530 MLY (1,989 MGY) of water while ORR uses approximately twice as much (14,760 MLY [3,900 MGY]). The ORR water supply system, which includes the city of Oak Ridge treatment facility and the ETTP treatment facility, has a capacity of 44,347 MLY (11,716 MGY).

Clinch River water levels in the vicinity of ORR are regulated by a system of dams operated by TVA. Melton Hill Dam controls the flow of the Clinch River along the northeast and southeast sides of ORR. Watts Bar Dam, located on the Tennessee River downstream of the lower end of the Clinch River, controls the flow of the Clinch River along the southeast side of ORR.

TVA has conducted floodplain studies along Clinch River, Bear Creek, and EFPC (TVA 1991). Portions of Y-12 lie within the 100- and 500-year floodplains of EFPC; however, proposed SWEIS facilities are located outside the 500-year floodplain (Figure 4.5.1–2).

Surface Water Quality. The streams and creeks of Tennessee are classified by TDEC and defined in the State of Tennessee Water Quality Standards. Classifications are based on water quality, designated uses, and resident aquatic biota. The Clinch River is the only surface water body on ORR classified for domestic water supply. Most of the streams at ORR are classified for fish and aquatic life, livestock watering, wildlife, and recreation. White Oak Creek and Melton Branch are the only streams not classified for irrigation. Portions of Poplar Creek and Melton Branch are not classified for recreation.

At Y-12, there are six treatment facilities with NPDES-permitted discharge points to UEFPC. Y-12 is also permitted to discharge wastewater to the city of Oak Ridge Wastewater Treatment Facility. The water quality of surface streams in the vicinity of Y-12 is affected by current and past operations. Despite efforts to reroute discharge pipes and to treat all wastewater from the plant processes, wastewater discharges from Y-12 are a major influence on water quality and flow in UEFPC. Stormwater discharges, groundwater discharges (either directly to the stream channel or collected in building sumps and discharged to UEFPC) and wastewater discharges contribute specific contaminants to UEFPC. Surface water contaminants in UEFPC are summarized in Table 4.5.1–1 and include metals (particularly mercury and uranium), chlorinated solvents, and radionuclides (especially isotopes of uranium) (DOE 1998b). Water quality in Bear Creek is influenced significantly by a groundwater hydraulic connection either directly to Bear Creek or to tributaries to Bear Creek. Contaminants in Bear Creek, from multiple formerly used waste burial trenches and pits, include nitrate, metals (e.g., uranium), radionuclides (e.g., uranium isotopes, ^{99}Tc), and chlorinated organics and are summarized in Table 4.5.1–1 (DOE 1997a and LMES 1997b).

Source: Tetra Tech, Inc.

FIGURE 4.5.1–1.—*Y-12 Area Surface Water Features.*

FIGURE 4.5.1–2.—*100- and 500-year Floodplains for Y-12.*

Surface Water Rights and Permits. In Tennessee, the state's water rights are codified in the *Water Quality Control Act*. In effect, the water rights are similar to riparian rights in that the designated usages of a water body cannot be impaired. The only requirement to withdraw from surface water would be a U.S. Army Corps of Engineers (USACE) permit to construct intake structures.

TABLE 4.5.1–1.—*Surface Water Quality, Upper East Fork Poplar Creek (Station 8 to Station 17) During Flow Augmentation, and Lower Bear Creek (BCK-0.63)*

			Tennessee Water Quality Criteria			
					Recreation	
Parameter	UEFPC (mean concentration)	Bear Creek	Domestic Use	Fish and Aquatic Life	Organisms	Water and Organisms
Metals (mg/L)						
Mercury	0.00091	!	0.002	0.00169	0.00005	0.00005[b]
Uranium	0.015	0.031	!	!	!	!
Lithium	0.041	!	!	!	!	!
Copper	0.007	!	!	0.0177[c]	!	!
Zinc	0.045	0.003	!	0.117[c]	!	!
Nickel	0.021	!	0.1	1.418[c]	4.6	0.61
Organics (Fg/L)						
Chloroform	2.8	!	!	!	4700	57
Tetrachloroethene	3.9	!	5	!	88.5	8
Carbon Tetrachloride	4[a]	!	5	!	44	2.5
Radionuclides (pCi/L)						
Gross Alpha	6.8	12.5	!	!	!	!
Gross Beta	3.7	8.62	!	!	!	!
Gamma	28	!	!	!	!	!

[a] One sample.
[b] Based on consumption of water and organisms. Applied to waters designated for domestic and recreational uses.
[c] Based on total hardness of 100 mg/L.
Note: BCK - Bear Creek kilometer.
Source: DOE 1997a, DOE 1998b, LMES 1997b, TDEC 1999b.

4.5.2 Groundwater

ORR Hydrogeology. ORR is located in an area of sedimentary rocks of widely varying hydrological characteristics. Two geologic units on the ORR, designated as the Knox Group and the Maynardville Limestone of the Conasauga Group, both consisting of dolostone and limestone, constitute the Knox Aquifer. A combination of fractures and solution conduits in this aquifer control flow over substantial areas and relatively large quantities of water may move rapidly over relatively long distances. Active groundwater flow can occur at substantial depths in the Knox Aquifer (92 to 122 m [300 to 400 ft] deep). The Knox Aquifer is the primary source of groundwater to many streams (base-flow), and most large springs on the ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits are reported to exceed 3,784 LPM (1,000 GPM).

The remaining geologic units on the ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) are aquitards, which consist mainly of siltstone, shale, sandstone, and interbedded limestone and dolostone of low to very low permeability. Nearly all groundwater flow in the aquitards occurs through fractures similar to the flow mechanism dominant in the aquifers. However, the absence of solution-enlarged fractures in the aquitards limits flow to a system of smaller and less connected fractures. The typical yield of a well in the aquitards is less than 4 LPM (1 GPM) and the base flows of streams draining areas underlain by the aquitards are poorly sustained because of such low flow rates. In areas underlain by aquitards, the combination of topographic relief and a decrease in bedrock fracture density with depth, restrict groundwater flow to shallow depths of the saturated zone and groundwater discharges primarily to nearby surface waters within the ORR (DOE 2000d).

The Knox Aquifer and ORR Aquitards can each be divided into a shallow soil and regolith unit and a deeper bedrock unit. The shallow unit consists of manmade fill, alluvium, colluvium, residuum, and weathered bedrock. In undisturbed areas an active storm flow zone, roughly equivalent to the zone of plant roots, carries a large percentage of infiltrating precipitation toward surface water streams. The influence of manmade fill on groundwater flow within the shallow unit is particularly important in Y-12 where pre-existing UEFPC stream channels have been filled and act as preferential groundwater flow paths (DOE 1998b). The bedrock unit consists of sandstones, siltstones, shales, and carbonates where groundwater flow occurs in fracture and/or conduit systems.

Y-12 Hydrogeology. Y-12, bound on the north by Pine Ridge and on the south by Chestnut Ridge, is located near the boundary between the Knox Aquifer and the ORR Aquitards. ORR Aquitards underlie Pine Ridge and Bear Creek Valley, which contains the main plant area of Y-12 and the disposal facilities of western Bear Creek Valley. The Knox Aquifer underlies Chestnut Ridge and the stream channels of Bear Creek and UEFPC. Bedrock formations comprising the Aquitards are hydraulically upgradient of the Aquifer, which functions as a hydrologic drain in Bear Creek Valley. Fractures provide the principal groundwater flowpaths in both the Aquifer and Aquitards. Dissolution of carbonates in the Aquifer has enlarged fractures and produced solution cavities and conduits that greatly enhance its hydraulic conductivity relative to the Aquitards.

Groundwater at Y-12 has been divided into three hydrogeologic regimes: UEFPC, Bear Creek, and Chestnut Ridge. A surface water divide at the west end of Y-12 effectively separates the UEFPC and Bear Creek hydrogeologic regimes with groundwater flow directions generally to the west in the Bear Creek regime and toward the east in the UEFPC regime. Bedrock beneath these two regimes is predominantly the ORR Aquitards. The Chestnut Ridge hydrogeologic regime, although hydraulically connected to the other two regimes, is distinctive in being developed on the underlying Knox Aquifer. In Bear Creek Valley, depth to groundwater is generally 6 to 9 m (20 to 30 ft) but is as little as 2 m (7 ft) in the area of Bear Creek near Highway 95. On Chestnut Ridge, the depth to the water table is greatest (>30 m [100 ft] below ground surface) along the crest of the ridge, which is a groundwater flow divide and recharge area. Groundwater in the Chestnut Ridge hydrogeologic regime tends to flow from west to east with elements of radial flow from the ridge crest north into Bear Creek Valley and south toward the headwaters of tributaries draining into Bethel Valley.

Recharge occurs over most of the area but is most effective where overburden soils are thin or permeable. Groundwater flow in the Aquitard and the Aquifer is primarily parallel to bedding, which in the Aquitard may or may not coincide with the direction of maximum hydraulic gradient calculated from field measurements. Cross bedding flows occur along permeable zones formed by fractures. The northern tributaries to Bear Creek (those exposed in western Bear Creek Valley and buried beneath Y-12) are possibly surficial expressions of the cross-cutting features.

In the Aquitard, most groundwater flow occurs in a highly conductive interval near the bedrock/residuum interface (water table interval). Flow occurs above the water table in response to precipitation when flowpaths in the residual soils become saturated and rapidly transmit water laterally (stormflow) down slope toward springs and seeps in drainage features, and vertically (recharge) to the water table interval. Recharge to the water table interval promotes bedding-parallel groundwater flow toward discharge areas in nearby cross-cutting streams. Although most active groundwater flow occurs at depth less than 30 m (100 ft) below ground surface, contaminants in groundwater more than 61 m (200 ft) below ground surface in the Aquitard indicate permeable flowpaths at depth.

In the Aquifer, most groundwater flow occurs at shallow depths (i.e., <30 m [100 ft] below ground surface) in an extensively interconnected maze of solution conduits and cavities. Below the shallow karst network, fractures provide the primary flowpaths. Flow in the shallow karst network in the Aquifer is relatively rapid and during rainfall results in rapid discharge to surface streams. Groundwater from the deeper flow system (>30 m [100 ft] below ground surface) discharges along major gaining reaches of Bear Creek. In the main plant area of Y-12, the surface water drainage system has been drastically altered by construction. Despite the alterations, groundwater discharges continue to the buried tributaries and to pre-existing spring locations. Actively pumping basement sumps in several buildings within Y-12 locally influence groundwater flow directions by drawing water toward the pump and lowering the water table. Basement sumps also contribute discharge to UEFPC.

There are no Class I sole-source aquifers that lie beneath ORR. All aquifers are considered Class II aquifers (current potential sources of drinking water). Because of the abundance of surface water and its proximity to the points of use, very little groundwater is used at ORR. Only one water supply well exists on ORR; it provides a supplemental water supply to an aquatics laboratory during extended droughts.

Groundwater Quality. Groundwater samples are collected semiannually or annually from a representative number of the monitoring wells throughout ORR. Groundwater samples collected from the monitoring wells are analyzed for a standard suite of parameters and constituents, including trace metals, VOCs, radionuclides, inorganics, and field parameters. Background groundwater quality at ORR is generally good in the near surface aquifer zones and poor in the bedrock aquifer at depths greater than 300 m (984 ft) due to high total dissolved solids.

Groundwater in Bear Creek Valley west of Y-12 has been contaminated by hazardous chemicals and radionuclides (mostly uranium) from past weapons production waste disposal activities (DOE 1997a). The contaminant sources include past waste disposal facilities sited on Aquitard bedrock north of Bear Creek. Former disposal facilities include the S-3 Ponds, the Oil Landfarm, the Boneyard/Burnyard site, and the Bear Creek Burial Grounds, all closed since 1988. Each site was used for the disposal of waste chemicals including acids, solvents, oils, radioactive material (e.g., uranium), and wastewater containing dissolved metals and radionuclides. As a result, the aquifers below disposal sites often contain accumulations of the organic solvents (dense nonaqueous phase liquids) and the groundwater beneath and downgradient of the disposal facilities is contaminated with nitrate, solvents (e.g., PCE, TCE, DCE), radionuclides (e.g., uranium isotopes and ^{99}Tc), and metals (e.g., uranium, cadmium, strontium). The distribution of groundwater contamination in the Bear Creek hydrogeologic regime is illustrated in Figures 4.5.2–1 through 4.5.2–3.

Historical monitoring of groundwater in the UEFPC Y-12 area has been used to define an area of contamination that extends throughout Y-12 and off-site to the east into Union Valley. The groundwater contamination is the result of a comingling of releases from multiple sources within Y-12. The most widespread contaminant types are VOCs such as the solvents PCE, TCE, DCE, carbon tetrachloride, and chloroform; and fuel components such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Other groundwater contaminants include nitrate, gross alpha activity (primarily uranium isotopes), gross beta activity (primarily uranium isotopes and ^{99}Tc). The most frequently detected metals are boron, beryllium, cobalt, copper, chromium, lead, lithium, mercury, manganese, nickel, and total uranium (DOE 1998b). The distribution of groundwater contamination in the UEFPC hydrogeologic regime is illustrated in Figures 4.5.2–1 through 4.5.2–3.

The Chestnut Ridge hydrogeologic area is dominated by several closed and operating disposal facilities including the closed Chestnut Ridge Security Pits, Chestnut Ridge Sediment Disposal Basin, United Nuclear Corporation Site, and five nonhazardous waste landfills. Groundwater monitoring data collected since the mid-1980s indicate limited groundwater contamination. Contaminants consist primarily of VOCs detected in scattered monitoring wells. The only definable VOC contaminant plume in groundwater is associated with the Chestnut Ridge Security Pits and extends approximately 792 m (2,600 ft) east of that facility. The distribution of groundwater contamination in the Chestnut Ridge hydrogeologic regime is illustrated in Figures 4.5.2–1 through 4.5.2–3.

Groundwater Availability, Use, and Rights. Industrial and drinking water supplies in the area are primarily taken from surface water sources. However, single-family wells are common in adjacent rural areas not served by the public water supply system. Most of the residential supply wells in the immediate area of ORR are south of the Clinch River. Most wells used for potable water are located in the deeper principal carbonate aquifer (305 m [1,000 ft]), while the groundwater contamination at Y-12 is primarily found above a depth of approximately 84 m (276 ft), with the exception of VOC contamination at the east end of Y-12 which has been found to extend to 171 m (560 ft) below ground surface.

Groundwater rights in the State of Tennessee are traditionally associated with the Reasonable Use Doctrine (Van der Leeden 1990). Under this doctrine, landowners can withdraw groundwater to the extent that they must exercise their rights reasonably in relation to the similar rights of others.